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HELIUM STARS HAVING BRIGHT LINES IN THEIR SPECTRA.

By PAUL W. MERRILL.

Nearly all of the brighter stars, and doubtless also of the fainter ones, may be considered as having a compact nucleus which radiates like a solid or liquid, surrounded by an atmosphere of various elements, each of which absorbs characteristic groups of wave-lengths. These outer gases themselves may be glowing, but they absorb more light than they emit, and give the spectrum the appearance of being crossed by dark bands.

At Harvard the commoner kinds of stellar spectra have been classified[1] as follows:—

B	helium stars	blue or white
A	hydrogen stars	
F	intermediate stage	yellow
G	solar stars	
K	post-solar	red
M	banded spectra	

The number of dark lines and the completeness of absorption increases as we go along the list. It is the idea of astronomers that, in general, a star runs the whole gamut of these types, though the time required is unthinkably long. One generation of observers is insufficient to detect the progression. Dr. CAMPBELL's discovery[2] that the average radial velocities of a large number of stars, if grouped by spectral types, increases from B to M, as listed above, makes it reasonably certain that the order is correct. Professor WILSON has recently shown[3] that this rule holds for total motion in space where this is known,

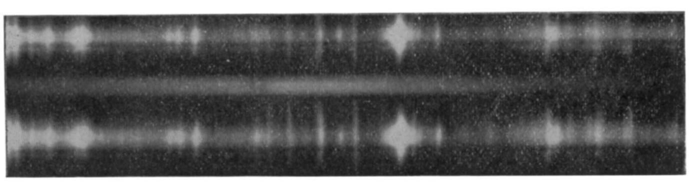
[1] Harvard College Observatory *Annals*, Vol. 28.
[2] Silliman Lecture, Yale University, January 31, 1910.
[3] Lick Observatory *Bulletin*, No. 214, and *Publications A. S. P.*, June, 1912.

and there is confirmatory evidence in the data of spectroscopic binaries.[1]

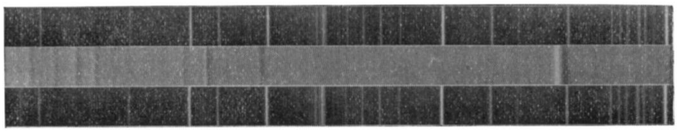
From considerations just referred to, B type stars are known as "early." The absorption of hydrogen and helium is predominant and characteristic. Other lines are often present, though usually faint, e. g., those of oxygen, silicon, magnesium. These stars are not distributed equally over the sky, even relatively, but are found in the greatest numbers in or near the Milky Way.

This important element helium occurs also in the chromosphere of the Sun; it forms four or five parts of every million of the Earth's atmosphere; it is found widely distributed in the Earth's crust, but practically always occluded in radio-active minerals. Next to hydrogen, it is the lightest of the elements. It is perfectly inert chemically.

From a masterly experiment by RUTHERFORD,[2] we know conclusively that when an atom of radium disintegrates it gives off an atom of helium. At first it is in a peculiar condition, owing to the high velocity of expulsion and to an electrical charge which it carries, but in a short time it is found to be nothing more nor less than ordinary inert helium. There are good grounds for believing that all of the helium in the Earth has come into existence from radio-active substances in this



SPECTRUM OF β *Piscium*, SHOWING A BRIGHT LINE SUPERPOSED ON AN ABSORPTION Hβ. PLATE M 45 A. 1911, JUNE 21.



P *Cygni*, SHOWING BRIGHT AND DARK LINES. 1911, JULY 3.

[1] *Lick Observatory Bulletin*, No. 181.

[2] *Philosophical Magazine*, **17**, 1909. p. 281.

sensational fashion. Such a remark with reference to the stars would be a pure speculation, though not an uninteresting, and possibly not even an unprofitable, one. Just at this writing comes the announcement from KÜSTNER[1] that uranium, and the direct product of radium called emanation, are making their marks in the spectrum of ENEBO's nova in *Gemini.* The lines of helium are present.

In 1866 SECCHI discovered a peculiarity in one of these helium stars. In examining the spectrum of γ *Cassiopeiæ* ($\alpha = 0^h\ 50^m.7$), he saw that it contained *emission* lines of hydrogen. Since then so many similar objects have been found that they are considered as a sub-class.[2] They have been called to the attention of astronomers principally by the lists of Harvard College Observatory[3] and the observations of CAMPBELL[4] at Mount Hamilton. The number known is at least sixty-three, being divided according to brightness as follows:—

Brighter than 3.0 magnitude	5
3.0 to 5.0 magnitude	29
Fainter than 5.0 magnitude	28
Variable	1

Within the range of spectroscopic surveys there are less than nine hundred Class B stars. The proportion of the bright-line stars to the whole class is not inconsiderable, particularly in view of the fact that it is probable that numerous existing cases have not been detected.

Though the glowing hydrogen of the atmosphere absorbs light from the nucleus, it may well be that in some cases it emits more than it absorbs, when, of course, the lines will appear bright on a continuous background. In many and perhaps all instances the bright lines are accompanied by broad absorption bands whose centers have about the same positions. This is explainable without great difficulty if we may consider the outer portions of the hydrogen layer as the most brilliant. This assumption is not extreme, as other conditions than temperature are known to affect light radiation. The lower levels under

[1] Harvard College Observatory *Circular,* No. 492.

[2] VOGEL's Class Ic. MISS CLERKE, "Problems in Astrophysics," Part II, Chapter 9.

[3] The latest list, including all previous ones, is Harvard College Observatory *Annals,* **56,** p. 182.

[4] *Astrophysical Journal,* **2,** p. 177.

great pressure may furnish the broad absorption band, with a narrower bright line within from the upper gas. The observed absorption varies in different stars from almost completeness to none at all or to a quantity so small as not to be readily discernible. Similarly, the bright lines vary from striking intensity to the faintest indications.

The following statements are quoted from Dr. CAMPBELL'S description[1] of his observations of bright hydrogen lines in stellar spectra:—

(a) Some stars contain both bright and dark hydrogen lines.

(b) The bright lines in such stars are those of greater wave-length; the dark lines are those of shorter wave-length.

(c) The intensities of the bright lines decrease as we approach the violet.

(d) The intensities of the dark lines increase as we approach the violet.

In the same spectrum the various hydrogen lines may present appearances which differ widely. For instance, the red line may be bright, one or two succeeding ones both dark and bright, and the remainder of the series toward the violet dark. This is, of course, in accord with the above rules in cases where the dark and bright series of lines overlap in the central part of the spectrum.

I am not acquainted with a single certain exception to rule (c) for Class B stars, but it does not hold for all stars having bright hydrogen lines. In fact, great differences of intensity are found in the *reverse order*. The star R *Leonis* (Type Md, $\alpha = 9^h\ 42^m.2$) is an example in point.

In many instances the bright lines superposed on the absorption bands are double. The components do not coalesce periodically as do lines of spectroscopic binaries where two spectra are visible, but remain permanently apart. A number of stars have periodic displacements of the lines as a whole, which have placed them in the lists of binaries. Sometimes the bright lines are present merely as intensified borders to the dark line,[2]

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[1] *Astrophysical Journal*, **2**, p. 177.

[2] $H\gamma$ of ϕ *Persei*. $H\beta$ and $H\gamma$ of β *Monocerotis*.

but more commonly they lie entirely within it. There may or may not be a more or less regular change of appearance, though the former is of rather rare occurrence. A notable example is Φ *Persei*[1] ($\alpha = 1^h\ 37^m.4$). In 1905 Hβ was dark in *Pleione* ($\alpha = 3^h\ 43^m.3$), though it had often been observed, previously, as bright. Changes have been recognized in the hydrogen lines of υ *Sagittarii* ($\alpha = 19^h\ 16^m.0$), a star which has a composite spectrum.

In some stars, lines other than those due to hydrogen show bright. Here again there may be variability, even when the hydrogen lines are unchanging. There were early observations of bright D_3 in γ *Cassiopeiæ* ($\alpha = 0^h\ 50^m.7$), but it certainly has not appeared so recently. The introduction of photography in stellar spectroscopy has frequently failed to confirm suspicions of variability based upon non-accordant visual observations. Very small weight should be attached to visual observations by any other than the most competent observers. The few absorption lines in these stars are generally very weak, as would be expected, since if some elements give emission lines, it is improbable that the absorption of other elements should strongly overpower their radiation. The absorption lines of the binary ϵ *Capricorni* ($\alpha = 21^h\ 31^m.5$) are variable.

There is, then, a subdivision of Class B stars having double bright hydrogen lines superposed more or less symmetrically on the corresponding absorption bands. No explanation of this phenomenon is at hand. There are other features also, as indicated above, whose causes are not clear. Besides this group there are a few anomalous specimens of which one or two must be mentioned.

Perhaps the most complex stellar spectrum thus far observed is that of the well-known doubly-eclipsing variable β *Lyræ* ($\alpha = 18^h\ 46^m.4$). The observations of it would fill volumes, and no details can be given here except to say that there are both bright and dark lines which change with baffling complication. A quadruple system is suggested by CURTISS;[2] the reader is referred to his extensive discussion.

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[1] LUDENDORFF, *Astronomische Nachrichten*, **186**, p. 16. J. B. CANNON, *Journal Royal Astronomical Society of Canada*, Vol. 4, p. 195.

[2] *Publications* of the Allegheny Observatory, Vol. 2, No. 11.

The spectrum of P *Cygni*[1] ($\alpha = 20^h\ 14^m.1$) resembles that of a nova, in having bright and dark lines apparently side by side, the emission line lying toward the red. The star is in fact a nova, having appeared in the year 1600. The light curve is that of a typical nova, except that the fluctuations were separated by years instead of days, and the fact that the final magnitude is the fifth instead of the twelfth or fifteenth. There are bright lines accompanied by absorption in all parts of the spectrum, from the ultra violet to beyond Hα. This remarkable spectrum continues year after year without appreciable change.

Descriptions of nearly all the stars mentioned in this paper can be found in Harvard College Observatory *Annals*, Vol. 28.

There is an interesting general question in regard to these stars which the future may answer. Are they an offshoot from the tree of stellar evolution? Or are they in the line of regular progression, but few in number because the time of passage through this condition is comparatively short; or because most of the stars have passed this stage in the process of development and there is a paucity of recruits?

Mount Hamilton, Cal., June, 1912.

THE CLUSTER TYPE OF STELLAR VARIATION.

By C. C. Kiess.

The first discovery of light variation in a star cluster was made in 1889, when Professor E. C. Pickering noticed a change in brightness of a star near the center of the cluster N. G. C. 5272. A year later Mr. D. E. Packer reported the discovery of two variables in the outskirts of the cluster Messier 5—a discovery shortly afterward corroborated by Dr. Common. But the chief credit for the detection of variables in clusters goes to Professor S. I. Bailey of the Harvard College Observatory, who, in the course of his duties at the Arequipa station, found that many of the *globular* clusters contain large numbers of variables. Thus, his first examination of photographs of the clusters M3 and M5 led to the discovery

[1] *Astrophysical Journal,* **10**, p. 319; *id,* **35**, p. 286; *Lick Observatory Bulletin,* No. 201.